

CLAIMS

What is claimed is:

- 5 1. A transmitter having a programmable amplifier comprises:

up-conversion module operably coupled to produce a radio frequency (RF) signal from
an I component of a low intermediate frequency (IF) signal, Q component of the low IF
signal, an I component of a local oscillation, and a Q component of a local oscillation;

10

programmable multistage amplifier operably coupled to amplify, based on a distributed
gain control signal, the RF signal to produce an outbound RF signal; and

15

control module operably coupled to generate the distribute gain control signal based on
an optimization of at least one of: power level, noise factor, and linearity of the
programmable multistage amplifier.

20

2. The transmitter of claim 1, wherein the programmable multistage amplifier
comprises:

first programmable amplifier operably coupled to produce an amplified RF signal by
amplifying the RF signal in accordance with a first gain control signal of the distributed
gain control signal; and

second programmable amplifier operably coupled to produce the outbound RF signal by amplifying the amplified RF signal in accordance with a second gain control signal of the distributed gain control signal.

5

3. The transmitter of claim 1, wherein the control module further comprises:

processing module; and

10 memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

generate a test signal to test for a desired power level setting of the programmable multistage amplifier;

15

provide an I component and a Q component of the test signal to the up-conversion module, wherein the up-conversion module produces an RF test signal that is amplified by the programmable multistage amplifier to produce an outbound RF test signal;

20 determine output power of the outbound RF test signal;

determine whether the output power of the outbound RF test signal is within a desired output power range;

2025-03-24 14:00:00

when the output power of the outbound RF test signal is not within the desired output power range, adjust the distributed gain control signal to produce an adjusted distributed gain control signal; and

5

repeat the providing the I and Q components of the test signal, the determining the output power of the outbound RF test signal with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining whether the output power is within the desired output power range, and the adjusting the distributed gain control signal until the output power is within the desired output power range.

10

4. The transmitter of claim 1, wherein the control module further comprises:

15 processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

20 generate a series of varying power level test signals to test linearity of the programmable multistage power amplifier;

sequentially provide the series of varying power level test signals to up-conversion module, wherein the up-conversion module produces a series of RF test signals based on the series of varying power level test signals, wherein the programmable multistage amplifier amplifies the series of RF test signals to produce a series of outbound RF test signals;

determine output power for each of the series of outbound RF test signals;

determine linearity of the programmable multistage amplifier based on the output power of the series of outbound RF test signals;

determine whether the linearity of the programmable multistage amplifier is within a desired linearity range;

when the linearity of the programmable multistage amplifier is not within a desired linearity range, adjust the distributed gain control signal to produce an adjusted distributed gain control signal; and

repeat the sequentially providing of the series of varying power level test signals to up-conversion module, the determining the output power for each of the series of outbound RF test signals with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining the linearity of the programmable multistage amplifier, the determining whether the linearity of the

programmable multistage amplifier is within a desired linearity range, and the adjusting the distributed gain control signal until the linearity is within the desired linearity range.

5. The transmitter of claim 1, wherein the control module further comprises:

5

processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

10

generate a test signal to test for noise level of the programmable multistage amplifier;

provide an I component and a Q component of the test signal to the up-conversion module, wherein the up-conversion module produces an RF test signal that is amplified

15 by the programmable multistage amplifier to produce an outbound RF test signal;

determine noise level of the outbound RF test signal;

determine whether the noise level of the outbound RF test signal is below a desired noise

20 level;

1007437-021202

when the noise level of the outbound RF test signal is not below the desired noise, adjust the distributed gain control signal to produce an adjusted distributed gain control signal; and

- 5 repeat the providing the I and Q components of the test signal, the determining the noise level of the outbound RF test signal with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining whether the noise level is below the desired noise level, and the adjusting the distributed gain control signal until the noise level is below the desired noise level.

10

6. The transmitter of claim 5, wherein the test signal further comprises one of:

a null signal; and

- 15 a signal having a known power level, wherein the determining the noise level is based on a determined signal to noise ratio.

7. The transmitter of claim 1, wherein the control module further comprises:

20 processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

determine a first optimal setting for the distributed gain control signal such that a noise level of the programmable multistage amplifier is below a desired noise level;

- 5 determine a second optimal setting for the distributed gain control signal such that output power of the programmable multistage amplifier is within a desired output power range;

determine a third optimal setting for the distributed gain control signal such that linearity of the programmable multistage amplifier is within a desired linearity range;

10

determine whether the linearity of the programmable multistage amplifier is within the desired linearity range, the output power of the programmable multistage amplifier is within the desired output power range, and the noise level of the multistage amplifier is below the desired noise level for each of the first, second, and third optimal settings for

- 15 the distributed gain control signal; and

when one or more of the linearity, the output power, and the noise level of the multistage programmable amplifier is not within the desired linearity range, the desired output power range, and below the desired noise level, respectively, for one or more of the first,

- 20 second, and third optimal settings, adjust the distributed gain control signal based on prioritization of the output power, the noise level, and the linearity.

8. A radio comprises:

receiver operably coupled to convert an inbound RF signal into an I component of an

inbound low intermediate frequency (IF) signal and a Q component of the low IF signal

5 based on an I component of a receiver local oscillation and a Q component of the receiver local oscillation; and

transmitter that includes:

10 up-conversion module operably coupled to produce a radio frequency (RF) signal from an I component of a low intermediate frequency (IF) signal, Q component of the low IF signal, an I component of a local oscillation, and a Q component of a local oscillation;

15 programmable multistage amplifier operably coupled to amplify, based on a distributed gain control signal, the RF signal to produce an outbound RF signal; and

control module operably coupled to generate the distributed gain control signal
20 based on an optimization of at least one of: power level, noise factor, and linearity of the programmable multistage amplifier.

9. The radio of claim 8, wherein the programmable multistage amplifier comprises:

first programmable amplifier operably coupled to produce an amplified RF signal by amplifying the RF signal in accordance with a first gain control signal of the distributed gain control signal; and

5

second programmable amplifier operably coupled to produce the outbound RF signal by amplifying the amplified RF signal in accordance with a second gain control signal of the distributed gain control signal.

10 10. The radio of claim 8, wherein the control module further comprises:

processing module; and

memory operably coupled to the processing module, wherein the memory includes

15 operational instructions that cause the processing module to:

generate a test signal to test for a desired power level setting of the programmable multistage amplifier;

20 provide an I component and a Q component of the test signal to the up-conversion module, wherein the up-conversion module produces an RF test signal that is amplified by the programmable multistage amplifier to produce an outbound RF test signal;

20240224200

determine output power of the outbound RF test signal;

determine whether the output power of the outbound RF test signal is within a desired output power range;

5

when the output power of the outbound RF test signal is not within the desired output power range, adjust the distributed gain control signal to produce an adjusted distributed gain control signal; and

- 10 repeat the providing the I and Q components of the test signal, the determining the output power of the outbound RF test signal with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining whether the output power is within the desired output power range, and the adjusting the distributed gain control signal until the output power is within the desired output power
- 15 range.

11. The radio of claim 8, wherein the control module further comprises:

processing module; and

20

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

generate a series of varying power level test signals to test linearity of the programmable multistage power amplifier;

sequentially provide the series of varying power level test signals to up-conversion

- 5 module, wherein the up-conversion module produces a series of RF test signals based on the series of varying power level test signals, wherein the programmable multistage amplifier amplifies the series of RF test signals to produce a series of outbound RF test signals;

- 10 determine output power for each of the series of outbound RF test signals;

determine linearity of the programmable multistage amplifier based on the output power of the series of outbound RF test signals;

- 15 determine whether the linearity of the programmable multistage amplifier is within a desired linearity range;

when the linearity of the programmable multistage amplifier is not within a desired linearity range, adjust the distributed gain control signal to produce an adjusted

- 20 distributed gain control signal; and

repeat the sequentially providing of the series of varying power level test signals to up-conversion module, the determining the output power for each of the series of outbound

RF test signals with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining the linearity of the programmable multistage amplifier, the determining whether the linearity of the programmable multistage amplifier is within a desired linearity range, and the adjusting the distributed gain control signal until the linearity is within the desired linearity range.

12. The radio of claim 8, wherein the control module further comprises:

processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

generate a test signal to test for noise level of the programmable multistage amplifier;

provide an I component and a Q component of the test signal to the up-conversion module, wherein the up-conversion module produces an RF test signal that is amplified by the programmable multistage amplifier to produce an outbound RF test signal;

determine noise level of the outbound RF test signal;

determine whether the noise level of the outbound RF test signal is below a desired noise level;

when the noise level of the outbound RF test signal is not below the desired noise, adjust the distributed gain control signal to produce an adjusted distributed gain control signal; and

5

repeat the providing the I and Q components of the test signal, the determining the noise level of the outbound RF test signal with gain of the programmable multistage amplifier adjusted in accordance with the adjusted distributed gain control signal, the determining whether the noise level is below the desired noise level, and the adjusting the distributed gain control signal until the noise level is below the desired noise level.

10

13. The radio of claim 12, wherein the test signal further comprises one of:

a null signal; and

15

a signal having a known power level, wherein the determining the noise level is based on a determined signal to noise ratio.

14. The radio of claim 8, wherein the control module further comprises:

20

processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

- 5 determine a first optimal setting for the distributed gain control signal such that a noise level of the programmable multistage amplifier is below a desired noise level;
- determine a second optimal setting for the distributed gain control signal such that output power of the programmable multistage amplifier is within a desired output power range;
- 10 determine a third optimal setting for the distributed gain control signal such that linearity of the programmable multistage amplifier is within a desired linearity range;
- determine whether the linearity of the programmable multistage amplifier is within the desired linearity range, the output power of the programmable multistage amplifier is
- 15 within the desired output power range, and the noise level of the multistage amplifier is below the desired noise level for each of the first, second, and third optimal settings for the distributed gain control signal; and
- when one or more of the linearity, the output power, and the noise level of the multistage
- 20 programmable amplifier is not within the desired linearity range, the desired output power range, and below the desired noise level, respectively, for one or more of the first, second, and third optimal settings, adjust the distributed gain control signal based on prioritization of the output power, the noise level, and the linearity.

15. A programmable multistage amplifier comprises:

first programmable amplifier operably coupled to produce an amplified signal by
amplifying an input signal in accordance with a first gain control signal;

5

second programmable amplifier operably coupled to produce an outbound signal by
amplifying the amplified signal in accordance with a second gain control signal; and

control module operably coupled to generate the first and second gain control signals

10 based on an optimization of at least one of: power level, noise factor, and linearity of the
programmable multistage amplifier.

16. The programmable multistage amplifier of claim 15, wherein the control module
further comprises:

15

processing module; and

memory operably coupled to the processing module, wherein the memory includes
operational instructions that cause the processing module to:

20

generate a test signal to test for a desired power level setting of the programmable
multistage amplifier;

provide the test signal to the first programmable amplifier such that the first and second programmable amplifiers amplify the test signal to produce an outbound test signal;

determine output power of the outbound test signal;

5

determine whether the output power of the outbound test signal is within a desired output power range;

10

when the output power of the outbound test signal is not within the desired output power range, adjust at least one of the first and second gain control signals to produce at least one adjusted gain control signal; and

15

repeat the providing of the test signal, the determining the output power of the outbound test signal with gain of the programmable multistage amplifier adjusted in accordance with the at least one adjusted gain control signal, the determining whether the output power is within the desired output power range, and the adjusting of the at least one of the first and second gain control signals until the output power is within the desired output power range.

20

17. The programmable multistage amplifier of claim 15, wherein the control module further comprises:

processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

- 5 generate a series of varying power level test signals to test linearity of the programmable multistage amplifier;

- sequentially provide the series of varying power level test signals to first programmable amplifier such that the first and second programmable amplifiers amplify the series of
10 test signals to produce a series of outbound test signals;

determine output power for each of the series of outbound test signals;

- determine linearity of the programmable multistage amplifier based on the output power
15 of the series of outbound test signals;

determine whether the linearity of the programmable multistage amplifier is within a desired linearity range;

- 20 when the linearity of the programmable multistage amplifier is not within a desired linearity range, adjust at least one of the first and second gain control signals to produce at least one adjusted gain control signal; and

repeat the sequentially providing of the series of varying power level test signals to first programmable amplifier, the determining the output power for each of the series of outbound test signals with gain of the programmable multistage amplifier adjusted in accordance with the at least one adjusted gain control signal, the determining the linearity of the programmable multistage amplifier, the determining whether the linearity of the programmable multistage amplifier is within a desired linearity range, and the adjusting of the at least one of the first and second gain control signals until the linearity is within the desired linearity range.

18. The programmable multistage amplifier of claim 15, wherein the control module further comprises:

processing module; and

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

generate a test signal to test for noise level of the programmable multistage amplifier;

provide the test signal to the first programmable amplifier such the programmable multistage amplifier produces an outbound test signal;

determine noise level of the outbound test signal;

determine whether the noise level of the outbound test signal is below a desired noise level;

- 5 when the noise level of the outbound test signal is not below the desired noise, adjust at least one of the first and second gain control signals to produce at least one adjusted gain control signal; and

- 10 repeat the providing of the test signal, the determining the noise level of the outbound test signal with gain of the programmable multistage amplifier adjusted in accordance with the at least one adjusted gain control signal, the determining whether the noise level is below the desired noise level, and the adjusting the at least one of the first and second gain control signals until the noise level is below the desired noise level.

- 15 19. The programmable multistage amplifier of claim 18, wherein the test signal further comprises one of:

a null signal; and

- 20 a signal having a known power level, wherein the determining the noise level is based on a determined signal to noise ratio.

20. The programmable multistage amplifier of claim 15, wherein the control module further comprises:

processing module; and

5

memory operably coupled to the processing module, wherein the memory includes operational instructions that cause the processing module to:

10 determine a first optimal setting for the first and second gain control signals such that a noise level of the programmable multistage amplifier is below a desired noise level;

determine a second optimal setting for the first and second gain control signals such that output power of the programmable multistage amplifier is within a desired output power range;

15

determine a third optimal setting for the first and second gain control signals such that linearity of the programmable multistage amplifier is within a desired linearity range;

20 determine whether the linearity of the programmable multistage amplifier is within the desired linearity range, the output power of the programmable multistage amplifier is within the desired output power range, and the noise level of the multistage amplifier is below the desired noise level for each of the first, second, and third optimal settings for the distributed gain control signal; and

when one or more of the linearity, the output power, and the noise level of the multistage programmable amplifier is not within the desired linearity range, the desired output power range, and below the desired noise level, respectively, for one or more of the first, 5 second, and third optimal settings, adjust at least one of the first and second gain control signals based on prioritization of the output power, the noise level, and the linearity.

2025-04-04